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5.—Fire in the jarrah forest environment

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Abstract

The fire history of he forest before and after colonisation is discussed and the adaption of the species to a fire climate emphasised. Type and severity of fires in virgin and cut-over forests are compared and the problems associated with fire protection are noted. The failure of a policy of complete protection from fire after 30 years, despite early success, is pointed out, and the problems associated with a sudden change to broadcast controlled burning are outlined.

Present methods of burning as dictated by research are defined and the prospect of successful rotational burning over the whole forest area is indicated.

Introduction

The jarrah *(Eucalyptus marginata* Sm.) forest is indigenous to the south-west corner of Western Australia, where it originally covered an area of some 13,000,000 acres, of which more than half has been alienated for other purposes —mainly agricultural. Four million acres of the better quality forest has been permanently dedicated as State Forest, under the Forests Act 1918-54, and the remaining area of 1,500,000 acres is classified as vacant Crown Land.

The main forest belt occupies the undulating plateau of the Darling Range at altitudes varying from 400 to 1600 ft. It extends from just north of Perth to merge with the karri *(E. diversicolor* F.v.M.) forest 200 miles to the south. Varying in width from 20 to 35 miles, its range is limited in the east by the 25-inch isohyet and in the west by the Darling Scarp; some outliers occur on the coastal plain. The species reaches its optimum development on the deep gravels on the middle and lower slopes of the laterite-capped ridges of the Darling Range. The tree is a grey stringy bark, which may reach a maximum of 6 feet in diameter and 140 feet total height.

Gardner (1942) describes the forest as a true sclerophyllous formation and remarks on the paucity of other tree species within the forest proper. Marri *(E. calophylla* R.Br.) is a minor associate and Western Australian blackbutt *(E. patens* Benth.) occurs on the moister soils, with bullich *(E. megacarpa* F.v.M.) and flooded gum *(E. rudis* Endl.) along some of the watercourses. Intrusions of wandoo *(E. redunca* Schauer *var. elata* Benth.) occur on the eastern fringe.

The main understorey trees are *Banksia grandis* Wield. and sheoak *(Casuarina fraseriana* Miq.f.) with a ground cover of relatively harsh-leaved shrubs. The ubiquitous and highly inflammable blackboy *(Xanthorrhoea preissii* Endl.) and the zamia palm *(Macrozamia reidlei* Gand.) occur throughout.

The climate of the region is typically Mediterranean with a well defined winter rainfall and near drought in the summer months. Total annual rainfall varies from 30 to 50 inches in the main forest belt with minimum falls in January and February when rainless periods of up to 30 to 40 days may be experienced. The ground temperature may reach as low as 25°F. in winter and screen temperatures exceed 100°F. on a few days each summer. A detailed climatic analysis covering the subject area has been published recently by the Bureau of Meteorology (Australia 1965). Because of this weather situation the forest is susceptible to fire for six months each year, and when subnormal winter rainfall is experienced it is possible to have a free running fire in this forest in every month of the year.

Natural resistance of the species to fire

Jarrah, recognised as one of the most fire resistant of the eucalypts, has had a fire history over perhaps thousands of years and the species has built up various forms of resistance to this phenomenon while reaching the status of a climax type.

Primarily, some trees in the forest carry seed each year, with particularly heavy seeding at irregular intervals. Light fires assist in the opening of the seed capsule and the seed then falls on the relatively weed free surface of a fertile ashbed. The young seedling develops a ligno-tuber which has been cited by Jacobs (1955), Harris (1955), and Loneragan (1962) as an outstanding adaption to the fire habitat.

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Under natural forest conditions the young jarrah sapling does not spring immediately from the seedling but exists as a semi-dormant procumbent shrub until the ligno-tuber has reached a diameter of 3-4 inches: usually a period cf 10-20 years or more. At this stage the stimulation of an opening of the canopy, removal of scrub competition and/or fire enables the advance growth to at last send up a single dynamic shoot from which the young tree develops.

As a further protective measure, jarrah develops a heavy bark up to 1½ inches thick in the mature tree. The bark is stringy in texture and finely fibrous on the outer surface when protected from fire. Light fires burn the surface bark only but with fires of greater intensity, the whole of the dry outer bark is consumed and this contributes markedly to the total heat production and, also, to the extension of a fire by throwing burning flakes of bark ahead to form "spot fires".

Recent work (Peet 1965) has shown that the oven-dry weight on the tree boles is of the order of 6 tons per per acre of which 4 tons is the dry outer bark. This is equivalent to a five year accumulation of litter on the forest floor (Hatch 1955) and is a significant fuel factor in severe fires.

Exfoliation of the outer layers of bark, blackened after a fire, takes 15-20 years and it is suggested that this period is required for equilibrium of bark production and normal bark shed and for maximum bark thickeness.

The species has developed a remarkable ability to coppice from dormant buds in the live bark and even mature trees, some hundreds of years old, may send up vigorous shoots from the stump after the tree has been felled. Similarly, dormant buds in the trunk and crown produce vigorous epicormic shoots after a severe fire and will rapidly replace the crown. Even when the crown is killed it is still possible for the tree to survive at least over a period of years, if sufficient numbers of epicormic shoots develop along the bole.

With these adaptations for survival, jarrah has developed the means to withstand all but the most severe fires.

Pre-colonisation era

As early as the 17th century the logs of such navigators as Pelsart, Vlaming, Jonk and Volkerfen made reference to smoke and fires on the mainland of this country. From these reports it must be assumed that the aborigines of this State, in common with those of eastern Australia (King 1963), were well acquainted with fire. Their nomadic habit of moving in small family groups from place to place in search of food suggests that at least one, and probably more fire-sticks were carried by each party. Evidence also points to a habit of burning patches of the country to provide more succulent growth as a lure for game, and King states that they used fire as a barrier to the movements of animals and to assist in their capture. Add to these possible uses of fire the number of cooking fires which must have been burning each day, in and around the forest, and there is little doubt that there were many sources of wildfire available at all times. There is no evidence to show that the natives made any particular attempts to confine their fires or to suppress any accidental outbreaks and it may be assumed that fires, once started, continued to burn as long as fuel was available and weather favourable.

Summer lightning is responsible for a number of uncontrolled fires each year and it must be accepted that this source of fire was also present before the arrival of the white man.

The vast extent of the original virgin forest with its carpet of leaf litter and low shrubs (Fig. 1) presented an ideal fuel bed through which a summer fire could creep for weeks on end, unhindered by anything but a rare shower or an occasional moist gully. With the possibility of a number of fires of this type occurring in the forest area at the same time, it is not unreasonable to assume that the forest was completely burnt through every 2-4 years. Even as late as 1925 the writer was able to observe three fires of this nature in unmanaged virgin forest east of Jarrahdale. These fires were alight in December and continued to burn until the following March, increasing in intensity as hot weather developed and waning to a faint smoke on the cooler days, until finally extinguished by steady rain. In 1930-31 a fire which started in early December moved steadily through the virgin forest, covering a distance of some 15 miles in 3 months. There was virtually no damage to the forest crop from this quietly moving low-intensity fire. This is a direct contrast to the Dwellingup fire in 1961, which covered 15 miles in 15 hours, causing complete defoliation and serious material loss.

Descriptions of the forest by the early settlers confirmed the opinion that the jarrah forests had been the subject of frequent light fires over many centuries, and that the species had so developed that it suffered the minimum damage from this treatment. They found a forest of massive, largely over-mature trees with 30-60 feet boles towering to 100-140 feet in height, with few understorey trees and a meagre cover of woody shrubs over a continuous carpet of leaves and twigs 0-4 years of age—a forest burnt every few years by relatively light fires burning mainly in the months of mid-summer. Flames from these light fires could have been no more than 1-3 feet high, in the limited fuel available, and caused little damage to the trunks of the trees and even less to the crowns towering high above them.

The post-colonisation era

One of the main reasons for the colonisation of Western Australia was the vast expanse of its forests and the great demand for suitable timber for shipbuilding by the Royal Navy following the decimation of its oak forests over previous centuries. Utilisation of this forest wealth commenced immediately after the arrival of the first settlers and one of the earliest export records (1836) of the new colony includes 10,000 cubic feet of Western Australian mahog-

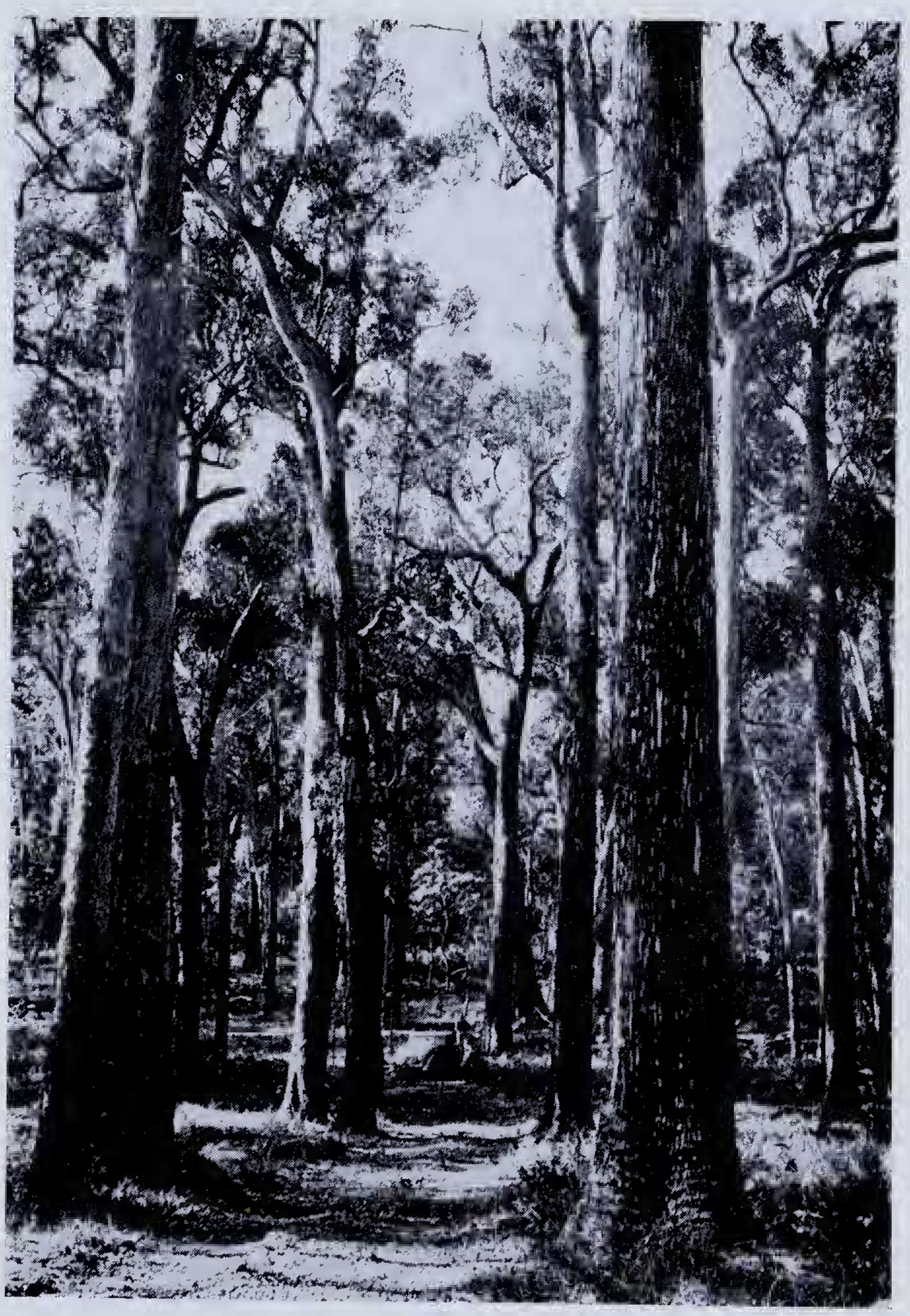

Figure 1.—Virgin jarrah forest.

any, as it was then called, for the naval dockyards in England. For the following ninety years exploitation of the jarrah forest continued unabated and uncontrolled.

Concentration of sawmilling operations during this early period was in the northern forest area, while the southern half of the forest region remained virtually untouched until after 1920.

In the period prior to 1920 nearly one million acres of the jarrah forest were cut over for the removal of 750 million cubic feet of logs, causing a reduction of almost 50% in the forest canopy.

While the operations of the sawmillers involved the removal of logs from the forest, the tops of the trees were left behind, and without organised control no action was taken to dispose of these piles of fuel, or to reduce the fire hazard that had been created. In consequence, when a fire did occur in the area, it was of extreme severity—a far different proposition from the light fire of previous centuries.

Measurements have shown that only half to one third of the standing tree is used by the sawmiller and as 20-30 tons of log timber were removed per acre, an equivalent weight of debris was left behind on the forest floor. This must be compared with the average two-year old fuel bed of the virgin stand. Hatch (1955) has found that the fall of litter in an average virgin jarrah stand is about one ton per acre per annum, with an accumulation of 2 tons in 3 years, allowing for normal decomposition over that period (Fig. 2). The addition of some 20-30 tons by the felling operation, even though some of this would have been heavy branch wood, was a highly significant factor in the burning regime of the forest. This mass of fuel, even if burnt in the summer following the milling operation, would have produced a fire of extreme severity, but where tops were felled in a recently burnt area they may have survived unburnt for two or three years, by which time the debris would have had time to dry and the resulting fire would have been even more damaging to the remaining trees and to any young growth which may have resulted from the felling operation.

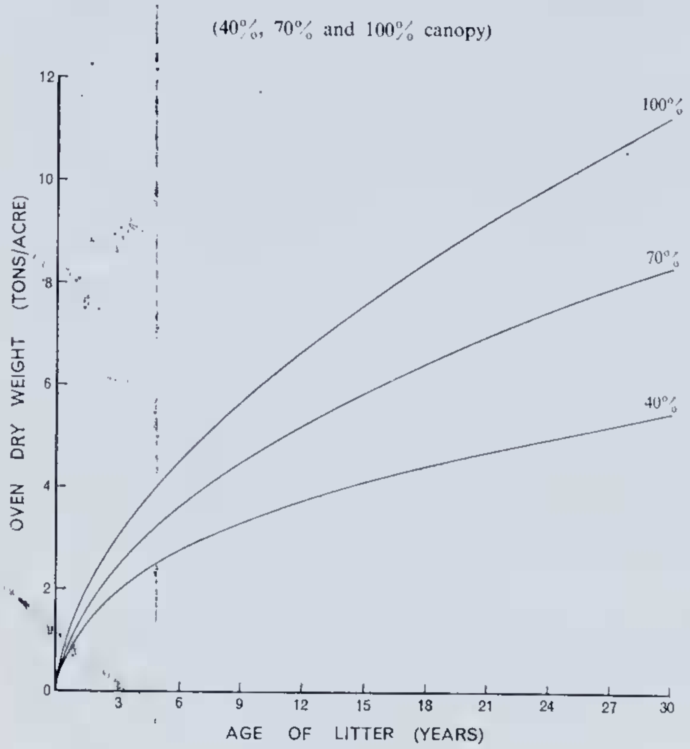

Figure 2.—Litter accumulation in the jarrah forest.

The holocaust arising from fires, under these conditions, caused complete defoliation and great damage to those trees remaining on the area (Fig.3): damage which permitted the ready ingress of insect borers and rot fungi. Although the unexploited virgin forest still remained an area regularly burnt and with a 0-4 year old fuel bed, the area of virgin forest immediately adjacent to the severe fire area also sustained serious damage—particularly in the crowns. As sawmilling operations became more extensive, severe fires became more frequent and more widely scattered throughout the forest area. At the same time, fires associated with clearing for agricultural purposes in the forest region were becoming more prevalent and an increasing source of forest fires.

In the early days of colonisation little notice was taken of these fires because they were small in relation to the forest area; however, as utilisation and clearing gradually increased in tempo fires increased in number, size and severity. Under the repeated onslaught of this type of fire the forest suffered heavily.

Gradually the public conscience awoke and there were periodic outcries for conservation and protection of this forest heritage. The first ordinance relating to the control of fire was passed in 1847 and the first Bush Fires Act in 1885. They did little more than define a prohibited burning period and, as they were not policed, had little effect on the problem.

Forest conservation and protection were virtually non-existent until the passing of the Forests Act in 1918, and even after this date it was some years before the new department was able to recruit sufficient staff to make much impression on the task before them.

Forest management and protection

Faced with the scarred and blackened boles of the cut-over areas and the grossly malformed stems of the young second growth trees, together with the mass of scrub and weed trees on the one million acres of cut-over forests, the newly appointed foresters found themselves with staggering problems in both fire protection and silviculture.

Fierce fires were the rule where sawmills were operating and serious damage had been inflicted, also, on parts of the remaining virgin stand.

Even in the southern forest region some fire trouble was being experienced, mainly from cattle drovers passing through the forest to the grazing country along the southern coast—and from clearing fires in settlement areas.

The problem was tackled from three angles:—

1. The continued protection of the virgin forest.
2. The reduction of debris following current felling operations—which were extending at the rate of 50,000 acres per annum.
3. The rehabilitation and protection of the backlog of 1,000,000 acres of forest cut over during the previous century and grossly damaged and degraded by periodic severe fires.

The protection of the virgin stand was relatively simple and was maintained by regular broadcast controlled burning in the cooler months of spring and autumn.

The mass of debris resulting from current felling operations had been, over the history of timber utilisation, the main cause of the disastrous fires in the forest area and the removal of this mass of fuel at the first suitable opportunity seemed to be the answer. The whole sawmilling operation was slowly brought under management as the following regime was introduced. Felling operations for each sawmilling permit were confined to an annual cutting coupe. This coupe was burnt through in advance of the felling operation and the trees marked for removal by the forester thus fell on a clean floor. The felled tops were lopped flat and any debris around the butts of standing trees was cleared away for a distance of 3 feet. The tops were then burnt in the following spring or autumn with minimum damage to the remaining stand. The area was thus rendered safe from fire for several years, and was included in the area receiving complete protection.

Figure 3.—Severely fire-damaged forest.

The backlog of older cut-over areas presented a more difficult problem and a compartment system of protection was devised where 500 acres of cut-over forest was given a suitable regeneration treatment involving the cutting down of the malformed regrowth at ground level, with a view to inducing a coppice crop from which future final crop stems could be selected. Understorey weed trees were felled and useless members of the original stand disposed of by ringbarking. This ringbarking, however, added considerably to the fire danger and difficulty of fire suppression and was abandoned after a few years.

Compartments were surrounded by a fireline about 2 feet 6 inches wide formed by a heavy scraper dragged by a horse. This fireline, or scraper track, defined the treated compartment on one side and a firebreak five chains wide on the other. These firebreaks were to be burnt every three years and the compartments protected from fire until the young growth had reached a height which would allow a light controlled fire to run through the area without causing crown damage.

Work in this direction proceeded steadily, centred on the forest settlements which were slowly being established throughout the forest area. Early operations were concentrated in the northern forest and moved slowly south as staff and money became available. For all operations access roads had to be developed, and in this reasonably undulating country were achieved at low cost. There are now 17,000 miles of forest roads of various standards throughout the south-west.

Detection of uncontrolled fires was necessary so that action could be taken for their suppression before they could menace protected forest and private property in and near the forest. A system of lookout towers situated on strategic high points throughout the forest area was planned for the location of fires by cross-bearings. The first was erected on Mount Gunjin in the Mundaring district in 1919 and the whole forest area is now adequately covered by 38 towers.

Suitable communication from lookout tower to forest headquarters and to the field firefighting gangs was essentiail. Initially, communication was by heliograph but this quickly gave way to an efficient earth return telephone system which eventually extended for 1,700 miles. Radio communication was attempted from Collie tower as early as 1928 but it was not until surplus equipment became available after World War II that radio came into general use to supplement the telephone. These high frequency sets had some disadvantages which unfortunately included poor reception during the worst fire weather conditions, but the system has been greatly improved by the recent substitution of V.H.F. units, of which 177 are now in operation.

Fire weather

The summer of 1933 was extremely hot and dry, with the worst heatwave on record in the month of February. Fires raged throughout the whole forest area, leaving a trail of damage in their wake. This prompted foresters to think more closely of the relationship between fires and weather, and in 1934 a fire weather research station was established at Dwellingup with the object of:—

1. finding some simple measure of fire danger at any time, and
2. exploring the possibility of forecasting fire weather.

Following the work of Gisborne (1928) and Stickel (1931) and after a study of the possibility of using individual or groups of weather elements. The fuel available varied from leaves to heavy branchwood and a further problem involved the selection of specimens of suitable size and shape which would give a reasonable representation of the moisture content of the faster burning debris. Jarrah leaf litter and various species and shapes of wood were tested and it was found that the most responsive and convenient unit was a half-inch diameter cylinder of locally grown *Pinus radiata*. For ease of measurements and calculation of moisture content a group of three cylinders with an initial over-dry weight of 50 grams was eventually used as a standard (Wallace 1936). A remarkable correlation was immediately apparent between the minimum daily moisture content and the average maximum hazard obtained from the personal estimates of field officers.

The term "fire hazard" was adopted for the burning conditions defined and the moisture content of the half-inch pine cylinder accepted in 1935 as a satisfactory measure of this factor. A graphical representation of moisture content and fire hazard was prepared for general use and standard ratings introduced (Low, Moderate, Average, High, Severe and Dangerous).

At this time a further problem arose in that there appeared to be a small but significant loss in oven-dry weight of the pine cylinders throughout the summer, with the result that apparent fire hazards read from the graph towards the end of the summer were too high. This was overcome by lowering the line monthly throughout the season and the use of new cylinders each year (Fig. 4).

No improved method of measuring current fire hazard has yet been found in this State and wood cylinder moisture content is still used as a basis for fire weather forecasting.

Forecasting fire weather posed a bigger problem than the measurement of current danger, and involved basic meteorological principles and the latest information available in the form of synoptic charts and upper air analysis. Reasonable progress was made in these early years and the effect of weather elements on the variation of fuel moisture content carefully analysed, but it was perhaps the regularity of the weather cycle over the southwest of this State that enabled an acceptable degree of accuracy in single observer forecasting to be achieved.

Fire weather forecasting was commenced at Dwellingup in 1936 and forecasts disseminated through the national broadcasting station. Two years later, this service was passed over to the Commonwealth Meteorological Bureau who have issued forecasts of fire hazard on every summer day since that time.

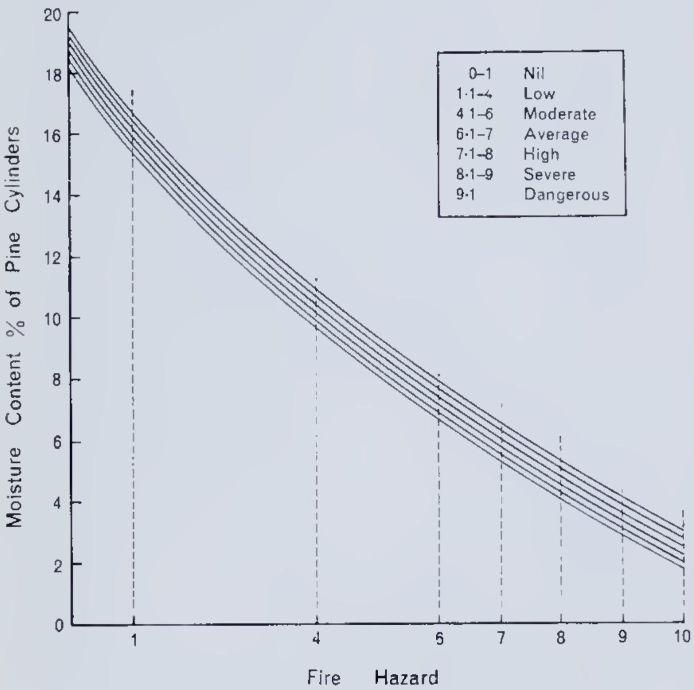

Figure 4.—Fire hazard in the jarrah forest.

Fire weather forecasts are composed of an estimate of the maximum fire hazard for the following day with details of wind force and direction, maximum temperature, relative humidity and other general weather information. With close co-operation between the State and Commonwealth authorities, a high degree of accuracy has been maintained over the past twenty-five years.

Summer weather over the forest area is governed by a series of high pressure systems which provide mild, dry conditions interspersed with periods of hot weather and high fire danger produced by a southern dip or trough from a tropical low pressure system usually centred off the north-west coast. Heat waves and maximum hazard occur when there is a southerly movement of the low pressure centre causing a stationary trough off the west coast. The relative instability of the air mass has an important bearing on the spread of a fire and its ability to throw spot fires ahead, and on the difficulty of suppression.

An analysis of the meteorological conditions relating to uncontrolled fires in Australia dating from 1914 was published by the Bureau of Meteorology (Foley 1947) and contains useful sketch maps of the weather situations for a number of major outbreaks in Western Australia.

Fire causes

O'Donnell (1945) has tabulated fire causes for the decade prior to 1943 and figures for the following 20 years are given in Figure 5. In general, they show that the forest region is the subject of over 300 fires each year and that there has been only a minor reduction in number over the period. Some major causes of fires have become less important over the years. Mill locomotives, once the main source of forest fires, have been reduced as a result of the steady replacement of steam by motor transport and the marked drop in fires from State railway locomotives in recent years has been influenced by the use of oil in place of coal. Fires from bush workers are less due to the introduction of power saws and reduction in number of fallers. Stockmen moving their stock through the forest areas, particularly in the south, and once the bane of the foresters' existence in that area, are no longer a source of trouble.

The most significant increases are in fires caused by lightning and by the Forests Department's controlled burning operations. The former, it is felt, is not due to any change in weather conditions but to improved and extended fire detection methods; previously a number of these fires were just not recorded while some were listed in other categories.

The number of fires escaping from departmental operations is directly related to the considerable increase in the area being burnt under the policy of extensive prescribed burning. It must be pointed out, however, that practically all of these fires occur in the cooler parts of the summer and that their area is small and little damage results.

Escapes from private property fires still present the main single cause of danger to the forest. These fires occur when the burning season opens in March and, burning in the driest part of the summer, are often of considerable size when they enter the forest. Second only to the fires in mill tops for the period prior to 1920, they have proved the most serious menace to the forest over the past 45 years.

Fire protection in the jarrah forest

In general, fire control organisation was aimed at:—

1. forward planning for controlled burning on a 3-year cycle;
2. early detection of wildfires;
3. rapid transport to the fire, and
4. speed in bringing the fire under control.

The main source of the initial devastating fires of the previous century was eliminated by the introduction of the top disposal operation. The total number of fires occurring was drastically reduced in the first decade of control but thereafter remained fairly constant in spite of continued attention to fire causes. Controlled burning of firebreaks and virgin forest areas appeared satisfactory and the backlog of cut-over country was gradually being brought under management. Methods had improved and the introduction of the knapsack spray as a major hand tool supported by the fire rake paved the way for organised firefighting units who received intensive training. More general use of motor vehicles after 1935 provided means of transporting gangs quickly to the site of a fire. Field fire gangs of 5-6 men were supplied with 3-ton trucks carrying a 200-gallon tank with low-down pump, knapsacks, rakes, axes, saws, portable telephone, first aid kit and iron rations. Tele-

FIRE CAUSES

(In 5-year Periods)

1944/45–1963/64 inclusive

	44/45–48/49		49/50–53/54		54/55–58/59		59/60–63/64		1944/1964 inc.	
	Total	Av.	Total	Av.	Total	Av.	Total	Av.	Total	Av.
Escape P/P. C.B.	293	58·6	472	94·4	446	89·2	320	64·0	1,531	76·5
Mill Locomotives	292	58·4	201	40·2	210	42·0	67	13·4	770	38·5
Escape F.D. C/B	113	22·6	115	23·0	188	37·6	226	45·2	642	32·1
W.A.G.R. Locomotives	278	55·6	88	17·6	162	32·4	44	8·8	572	28·6
Travellers	152	30·4	103	20·6	121	24·2	150	30·0	526	26·3
Deliberately Lit	45	9·0	197	39·4	87	17·4	114	22·8	443	22·1
Hunters and Fishers	123	24·6	102	20·4	102	20·4	84	16·8	411	20·5
Lightning	15	3·0	68	13·6	84	16·8	175	35·0	342	17·1
Children	38	7·6	36	7·2	87	17·4	104	20·8	265	13·2
Bush Workers	76	15·2	80	16·0	49	9·8	46	9·2	251	12·5
Mill Surrounds	33	6·6	40	8·0	61	12·2	43	8·6	177	8·8
Other Government Departments	30	6·0	38	7·6	60	12·0	33	6·6	161	8·0
Householders	34	6·8	38	7·6	49	9·8	38	7·6	159	7·9
Stockmen and Leaseholders	83	16·6	11	2·2	13	2·6	....	....	107	5·3
Tractors	2	0·4	9	1·8	12	2·5	31	6·2	54	2·7
Mine Surrounds	15	3·0	5	1·0	10	2·0	12	2·4	42	2·1
Firewood Cutters	23	4·6	9	1·8	8	1·6	2	0·4	42	2·1
Navvies	18	3·6	11	2·2	5	1·0	2	0·4	36	1·8
Gas Producers	13	2·6	....	....	....	....	....	....	13	0·6
Escape Prev. Fires	....	..	3	0·6	9	1·8	....	....	12	0·6
Motor Vehicles	....	....	....	....	5	1·0	....	....	5	0·2
Power Mains	....	....	....	....	1	0·2	3	0·6	4	0·2
Unknown	100	20·0	97	19·4	135	27·0	128	25·6	460	23·0
Totals	1,776	....	1,723	....	1,904	....	1,622	....	7,025	....

Figure 5.—Causes and distribution of fires.

phone contact was maintained with forest headquarters or the nearest lookout tower and the fire gang coulld be despatched to any outbreak without loss of time. Gangs were trained to a high peak of efficiency; morale was high and it seemed as though the fire problem was well under control. Newly cut-over areas of 50,000 acres were being coped with and an average of a further 50,000 acres of the backlog brought under protection each year.

In 1945, however, O'Donnell, the forest fire control officer pointed out that, during the previous three years controlled burning operations had lagged seriously and that the planned programme had not been maintained. He considered that this was to some extent due to lack of manpower during the war but also emphasised that the hazards of firebreak burning had increased considerably as areas protected from fire had, over the years, accumulated masses of debris in the form of leaf litter, branchwood and dead shrubs and, also, that the unburnt bark of the trees had reached a highly inflammable condition. Burning of firebreaks around these protected areas was becoming increasingly difficult; sparks caused fires in the adjoining protected country which were difficult to suppress, and time lost in suppressing these hop-over fires was time lost in controlled burning. Furthermore, as debris in the protected areas increased and the danger in burning protective firebreaks increased in the same order, cooler weather had to be selected for controlled burning activities and this in turn reduced the number of days on which the burning could be attempted and the total amount of burning which could be completed. Factors generally adverse to successful fire protection were snowballing.

Operations were streamlined by increasing the size of compartments to 1,500 acres and reducing the mileage of firebreaks involved; firelines were straightened, widened and improved to carry motor transport; heavy duty fire equipment in the form of 5-ton trucks loaded with 600 gallon tank and power pumpers was introduced. This improved the situation for a period but fires in long-protected areas were still causing grave concern. Breakaways from controlled burning were common and, even though these occurred in the milder spring weather, were still serious. Where uncontrolled fires started in mid-summer in these long-protected compartments the resulting fires could be contained only after the loss of large areas, at considerable expense, and with the assistance of firefighting forces from outside the home district.

Following extensive fires in forest east of the Albany Road in 1949, and the Plavins fire of some 30,000 acres in 1950, it was becoming apparent that the ability of the firefighting forces to control fires, within the limits of forest economy, in the 2,000,000 acres then receiving protection was in doubt. Further trouble and declining morale of the firefighters forced a serious reconsideration of policy. In 1954 the momentous decision was made to replace the complete protection policy of the past 30 years with one of prescribed, broadcast burning in an attempt to reduce the damage from wildfires in previously protected forest.

This change in policy produced its own complex of problems, not the least of which was to break down the hazard built up in the protected areas over a long period of years. It was impossible to burn this heavy accumulation of fuel, even in spring, without serious damage to the growing stock. The only answer was to reduce the debris by periodic fires, the first of which would need to be in the winter months when, unfortunately, the days on which burning could be undertaken were limited. Rather than concentrate on completely reducing the litter on a small area, it was decided to burn the top litter over the greatest possible area but there was little doubt that 10-15 years would be needed for the complete reduction of the accumulation of the previous 25 years if serious damage to the forest regrowth was to be avoided. There was a further complication because, while the flash fuels were being removed over a wide area, the sections burnt first were themselves again increasing their fuel from the annual leaf fall. Progress was slow and some serious breakaway fires still occurred, but the position was improving gradually as the tempo of controlled burning increased.

The forest area at Dwellingup was typical of the results of a tight protection policy. In an area of some 450,000 acres, 90% was under full protection by 1954. There had been an all-out effort to reduce leaf litter accumulations of up to 25 years over the seven years to 1961 but success had been only partial for, while the top litter had been removed over a large part of this area, critical amounts of fuel remained over wide areas, broken only by occasional recently burnt firebreaks and some more extensive areas of broadcast burn. The position was serious then in January 1961, when a widespread conflagration was started by 22 lightning fires in 24 hours. This wildfire ultimately developed into the most extensive fire in the jarrah forest in the 40 years of fire protection. It covered 350,000 acres of forest, and air-photos and subsequent field checks revealed that there had been 65,000 acres completely defoliated, 120,000 acres where the majority of the crowns were browned (that is, the leaves killed but not burnt off), and the remaining 165,000 acres relatively undamaged. If medical terms could be used these fires could be referred to as third degree, second degree, and first degree burns respectively.

Practically the whole area of this fire was in country cut-over variously between 5 to 60 years and carrying young jarrah pole growth of a similar age range together with the remainder of the old forest trees not removed in the original or subsequent milling operations. Debris on the forest floor varied with age since the last cutting and the protective treatment over the previous 25 years.

The damage sustained in the third degree burn included the death of a proportion of the old veterans, "crown kill' in others, with epicormic response in the boles and, in the more vigorous trees, defoliation with crown recovery. Serious damage to the younger members of the stand occurred and many of the suppressed trees were killed. The dominants of the regrowth stand, however, survived reasonably well but were the subject of bole damage in the form of butt scars and dead patches along the length of the trunk. This is particularly serious in trees halfway to maturity as this bole damage will later cause serious defects in the middle wood of the mature log—the region where the best timber in size and soundness may normally be expected. The outstanding power of recovery of jarrah has already been referred to and the difference in appearance of these heavily burned stands after a period of 3 or 4 years is remarkable.

The area of second degree burn suffered somewhat similar damage to the above, but of a lesser order. Complete crown defoliation was rare but although some old trees were killed bole damage was less and recovery of the dominants produced less bole epicormics. In both areas dense fireweeds, particularly *Acacia pulchella*, thrived and these will be a serious handicap to forest operations and controlled burning during the current decade.

The first degree burn occurred over those areas which had been the subject of satisfactory controlled burning in the previous two years. The results were similar to those expected with controlled burning on a hot day and caused only the minimum of damage. It did, however, show very clearly the value of prescribed protective burning in reducing damage from wildfires even under the worst possible weather conditions.

Prescribed broadcast burning

In recent years considerable research has been undertaken into the factors governing periodic controlled burning and its practical application to the protection problem.

It must be emphasised that controlled (or prescribed) burning is aimed at the reduction of fuel over a wide area within the boundaries specified and within the scorch heights acceptable. It does not seek primarily to remove all litter from the forest floor at any time, but is concerned with maintaining the forest in a condition where wildfire may be readily contained and damage kept to a minimum. In view of the great area involved the operation is extensive rather than intensive, and in the jarrah forest is directed towards a complete cover of the forest area every five years. This means the prescribed burning of more than 800,000 acres per year and cannot be achieved without the maximum effort and efficiency of all fire protection personnel.

McArthur (1962) working in both jarrah and Eastern States eucalypts has produced data of considerable value and has devised a series of graphs from which rate of spread, flame height and scorch height may be determined for varying conditions of weather, fuel quantity and fuel moisture content. Peet (1962-65) working from the Fire Research Station, Dwellingup, has modified McArthur's findings to deal specifically with jarrah and the practical problems associated with controlled burning in this forest.

A number of interesting criteria have been produced by these workers who suggest that the critical scorch height which should not be exceeded is 20 feet and that the relationship of scorch height to flame height in the jarrah forest is of the order of 7:1 in summer, and 14:1 in autumn. This limits the flame height to 3 and 1½ feet respectively. While this constitutes the maximum acceptable it borders on the risky and the greater part of the area to be burned should be covered by a less intense fire. McArthur's suggestion that it should be possible to step over the flame in a controlled burn is a fair guide to acceptable fire intensity.

The practical application of precise criteria for burning is most important from the angle of total area to be burnt. The prescribed burning of 800,000 acres per year with a total force of about 300 men means that each individual must burn over 2700 acres per season. On an average, a total of only 45 days of suitable controlled burning occur during the spring and autumn months. Forty acres per manhour, using fusee matches, has been suggested as a desirable norm for controlled burning but it seems doubtful whether this can be maintained over a whole season and a figure of 20 acres would seem more conservative for the whole forest range. This would require full use of every available burning day outside the summer months. If 20 acres per hour can be maintained the prime cost of the operation would be 5 cents per acre, or about one cent per acre per annum on a five year burning rotation. This is an extremely low fire insurance on a valuable crop of standing timber. Much higher insurance values could be accepted but the critical factors are availability of manpower and money and the huge area which must be burnt annually if prescribed burning policy is to be effective.

The designed method of burning on an area basis is by a grid system of spot fires, each small fire being left to burn out to meet its neighbors. It is obvious that the wider the spacing between the spots the greater the area burnt over by the gang in one day. The widest spacing is desired for another season—the junction zone between any two fires is an area of more intense fire, flame height and scorch height. Where spots are 1 chain apart 50% of the area may be subjected to the higher intensity fire; with 10 chain spots the figure is reduced to 10%.

A series of tables has been evolved to assist in the technique of controlled burning within the limits of a satisfactory reduction of the forest fuel and an acceptable scorch height for the section of forest concerned. The method is based on the forecast maximum hazard for the day, corrected for amount and period since last rain. To this adjusted fire hazard is applied the wind force, in miles per hour, (taken from the nearest lookout tower) to assess the forward rate of fire spread in a 5-year old leaf litter which is taken as the standard. The rate of spread in 5-year old litter is then corrected for the actual age of litter in the area to be burnt, and this same table gives the scorch height for the conditions prevailing. If the scorch height is acceptable then the next table, taking into account the number of hours available for the operation, indicates the distance between the lines of spots. For safety reasons the lines are run at right angles to the wind direction and the spots along the lines are half the distance between the lines.

In a search for more rapid and effective methods of controlled burning over extensive areas in a short period field trials have been undertaken recently using an airborne incendiary as the lighting agent.

A light push-pull twin-engined aircraft was used in this project, flying along previously defined parallel lines and dropping small incendiaries from a height of 300 feet above treetop level. Radio contact was maintained with a ground control and check markers (hydrogen-filled meteorological balloons) were established at strategic intervals.

Effective lighting was carried out over 52,000 acres at the rate of 3000 acres per hour of incendiary dropping time, at a cost only slightly higher than the normal ground operation.

This form of lighting has distinct advantages over the normal methods. The whole operation is speeded up and large areas may be stripped when only limited periods of suitable weather are available. Periodic shortages of manpower could become less important and forests with limited roading would be more readily protected. There is little doubt that with improved techniques aerial lighting heralds a major advance in the controlled burning programme.

Growth rates following fire

An interesting sidelight on severe fires leading to defoliation or browning of the jarrah pole crowns was revealed after the Plavins fire in

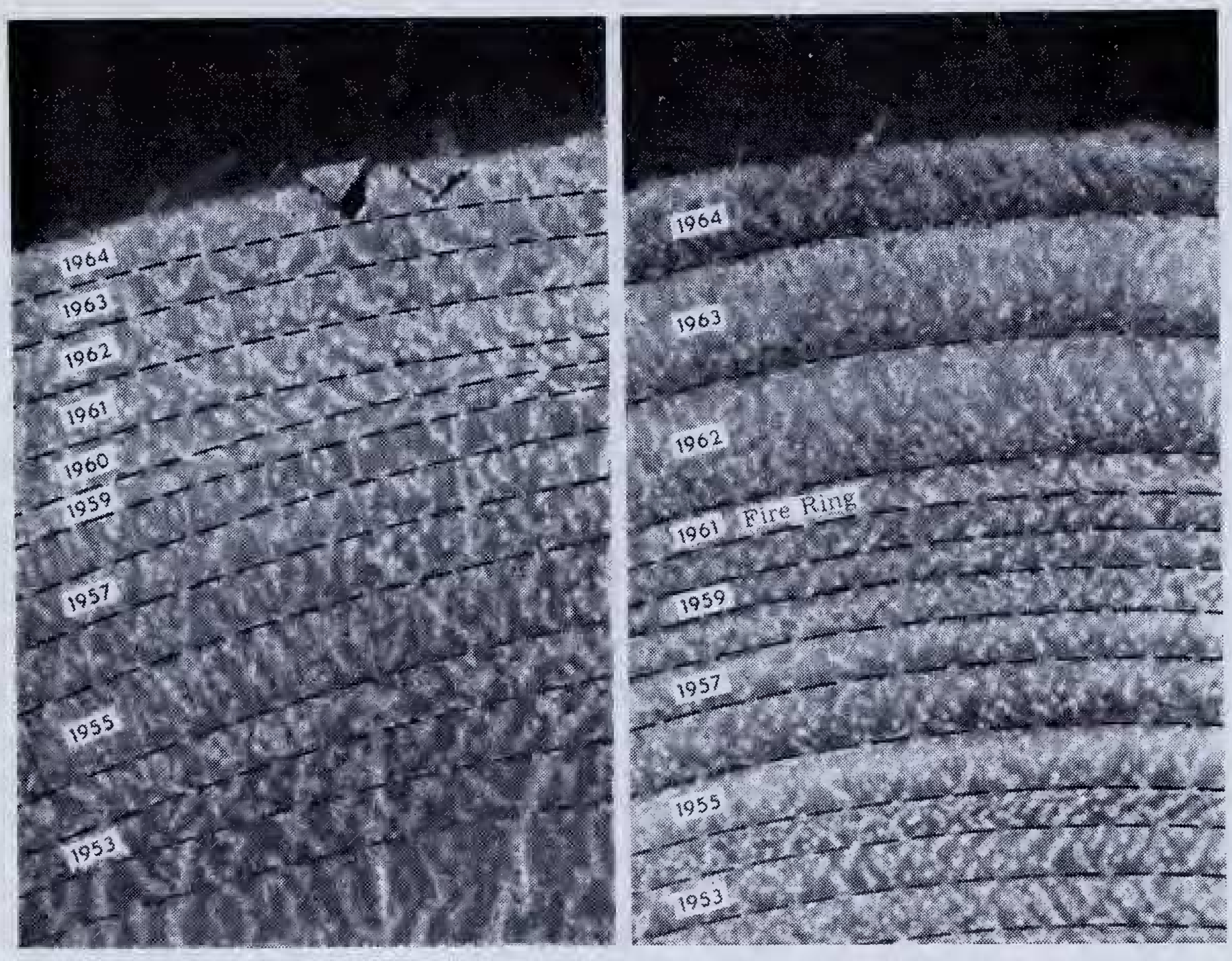

Figure 6.—Increased growth rate following 1961 fire (right) compared with unburnt control (left).

1950, when it was found that there was a virtual cessation of growth immediately after the fire but a surge of growth for the following four or five years. Further work on this phenomenon has been carried out since the Dwellingup fire in 1961 and annual basal area increments up to four times greater than the pre-fire figures have been measured (Fig. 6). It is thought that this is due to the sudden availability of ash nutrients following the fire, to the temporary removal of scrub and weed-tree competition, the reduction of numbers in the major stand through death of some members and the flush of vigorously synthesising young growth in the new epicormic crown. While this increased growth rate is something on the credit side of a severe fire, it certainly does not offset gross mechanical damage to the growing stock and cannot be used as an argument in favour of massive fires at infrequent intervals.

Summary

Uncontrolled fires of the first century after the colonisation of Western Australia left a legacy of devastation to the forest service established after 1918. One million acres of the forest area had been cut over and seriously damaged by uncontrolled fires, sawmilling was proceeding at a high level and newly cut areas were increasing at the rate of 50,000 acres a year. As forest centres became established silvicultural operations to replace the fire-damaged forests were instituted and went hand in hand with protection of these areas. Disposal, by controlled burning, of tops left by current milling operations was undertaken annually as soon as weather conditions were suitable, and the major source of fuel which had caused the severe fires of the past was eliminated.

Complete protection of compartments by a fire-break system while the new growth became established and attained a height growth above the scorch height of a controlled fire was maintained and extended to cover past cut-over areas. This form of protection, combined with immediate and vigorous suppression of wildfires, was successful for a period of 25 years in reducing the severity of uncontrolled fires and protecting substantial areas of forest during the regrowth period. While this was reasonably satisfactory over 2 million acres, it could not be applied over the total forest area for economic reasons.

The policy of complete protection, however, gradually built up its own problems by the accumulation of debris in the protected areas. This eventually reach the stage where the rate of protective burning was slowed down to a dangerously low level and the number of damaging fires was increasing in the long-protected areas. In spite of increased expenditure and the provision of more and heavier equipment, it became necessary to abandon the protection policy and institute one of broadcast controlled burning. This was no immediate solution to the problem as the fuel accumulated over 2,000,000 acres would take 10-15 years to reduce to safe proportions. The unfortunate and disastrous fires at Dwellingup in 1961 did little to help the position except that it did increase the emphasis on research into prescribed burning and, although this work must continue, some of the results are already being put into practical use, leading to a marked improvement in the efficiency of controlled burning techniques.

Now that most of the heavy fuel accumulations have been eliminated the present policy should provide more satisfactory protection to the whole of the 4 million acres of jarrah forest area, at the same time providing a reasonable balance between the silvicultural requirements of the stand and the need for protection from serious fires. Wildfires will continue while the causes remain, but these fires will be more difficult to start and more readily controlled where the maximum accumulation of litter over the greater part of the forest will be no more than five years of age.

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